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Managing Water in the West

Climate Change Impacts on Water Supply Predictability

Levi Brekke (Reclamation, Technical Service Center)

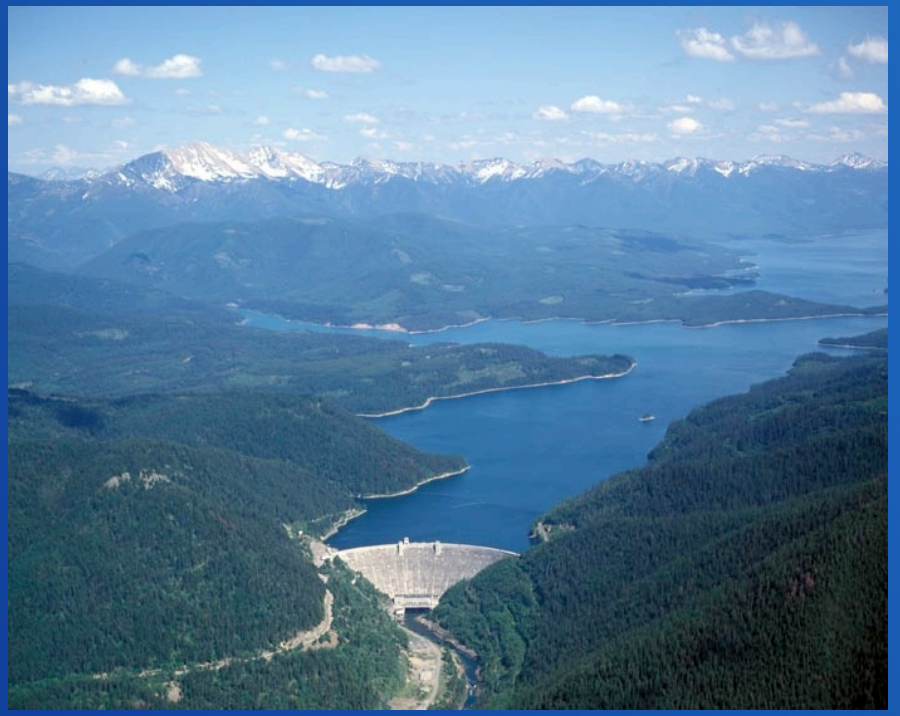
Co-Investigators: Kevin Werner (NWS CBRFC), Donald Laurine (NWS NWRFC), David Garen (NRCS NWCC)

AMS Short Course "Hydrologic Prediction and Verification Techniques with a Focus on Water Supply", 23 January 2011, Seattle, WA (Content originally presented at MtnClim 2010, Blue River OR)

U.S. Department of the Interior
Bureau of Reclamation

Context

- Seasonal water supply forecasts inform Western U.S. water management
- Calendar influenced by the “snow year”
- ~Goal: predict Spring-Summer Runoff given present snowpack and antecedent precipitation



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Research Questions

- How will climate change impact seasonal water supply predictability?
  - For many western U.S. basins, snowpack contributes to predictability.
  - Loss of snowpack should eventually impact predictability (Dettinger & Culbertson 2008).
- How can we factor predictability changes into long-term assessments of reservoir operations and water management?

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Study #1:
Transient Predictability, eight western U.S. basins

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Approach

1. Select Ensemble of Climate Projections, 1950-2099.

2. …make Ensemble of Basin Hydroclimate Projections (P, SWE, Runoff), 1950-2099
   - process-based hydrologic simulation modeling

3. …make Ensemble of Forecast Projections, 1981-2099
   - series of forecast models within each hydroclimate projection
   - decadal model updates, similar to NRCS procedures

4. Evaluate validation forecast skill through time as climate changes.
   - Various metrics (r^2, RMSE, ratio of RMSE to Mean Actual)

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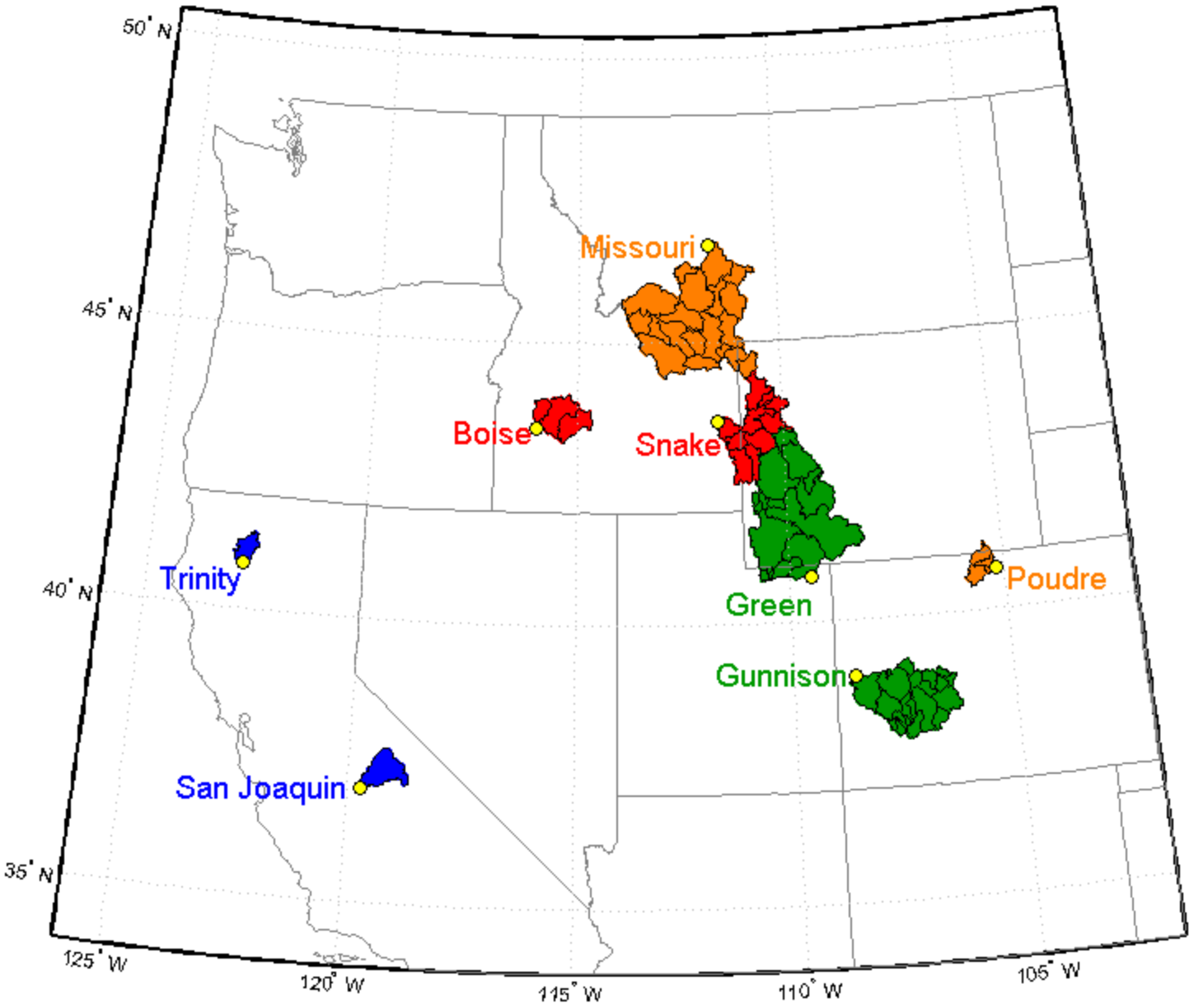
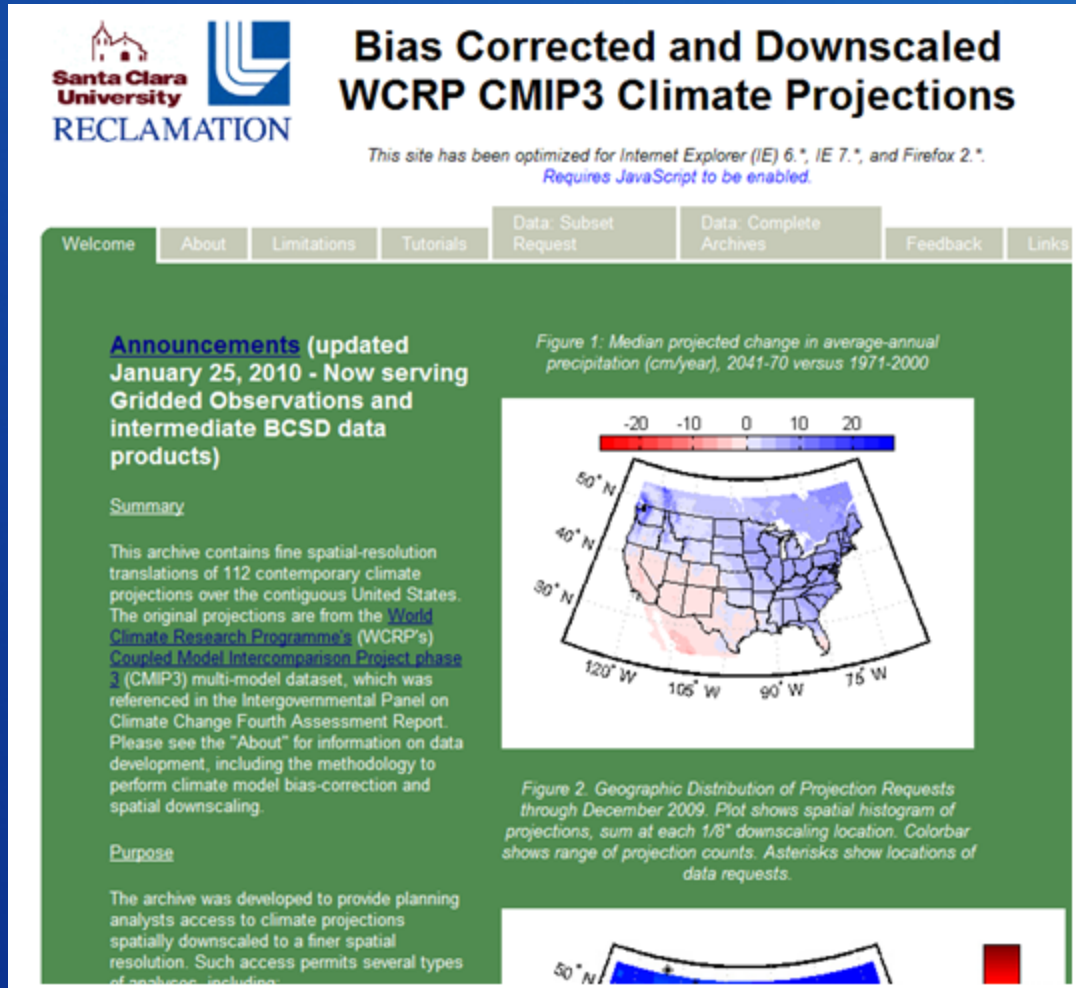

Case Study Basins
50° N
45° N
40° N
35° N
125° W
120° W
115° W
110° W
105° W
Missouri
Boise
Snake
Green
Poudre
Trinity
Gunnison
San Joaquin

Selected Climate Projections (Bias-corrected, Spatially Downscaled)

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/

- 112 CMIP3 Projections
  - 16 models, 3 emission scenarios, and multiple initializations for model-emissions combination
- Variables:
  - Precipitation Rate (mm/day)
  - Mean Daily Temperature (°C)
- Temporal Coverage and Resolution
  - 1950-2099, monthly
- Spatial Coverage and Resolution
  - Contiguous U.S., 1/8° (~12km x 12 km)
- Developers
  - Reclamation, Santa Clara University (Ed Maurer), LLNL

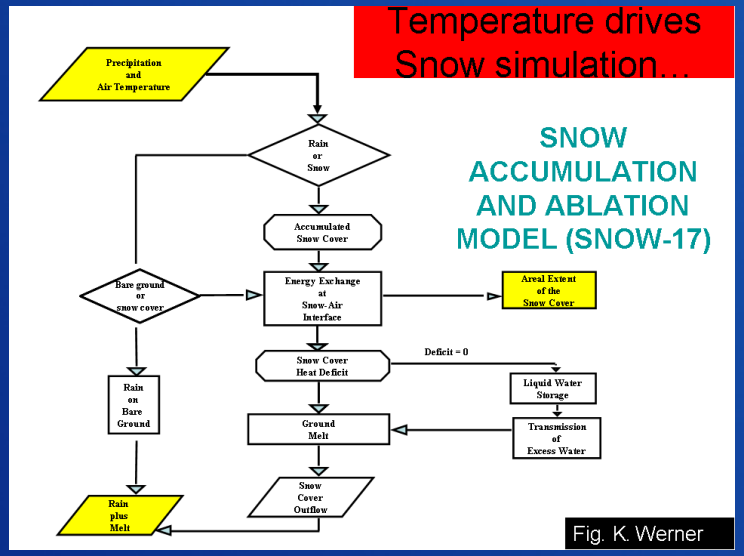


Making Hydroclimate Projections

Simulation Model:

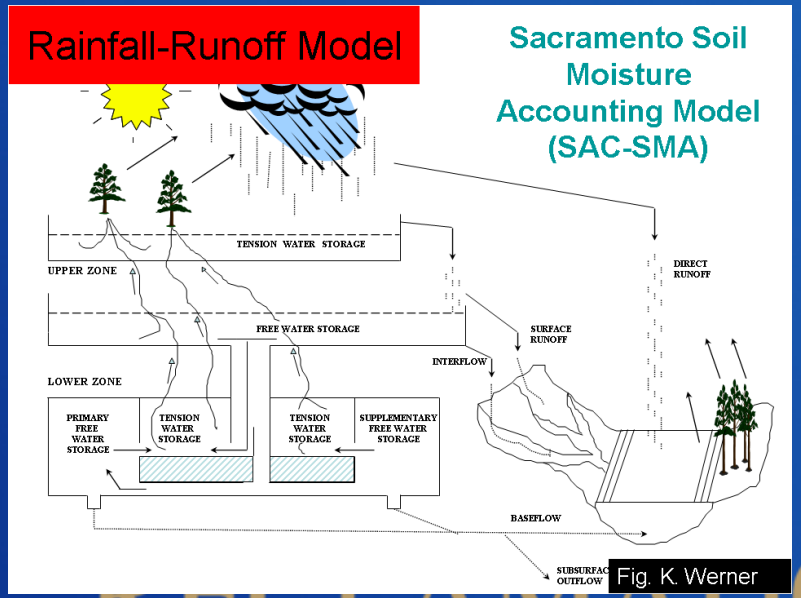
SacSMA/Snow17

Basin-applications from four collaborating NWS River Forecast Centers (Missouri Basin, Northwest, Colorado Basin, California-Nevada)



Application:

1. generate weather inputs following Wood et al. 2004, translating from monthly BCSD data into 6-hourly weather
2. use Hamon to adjust input PET given T change
3. simulate runoff.



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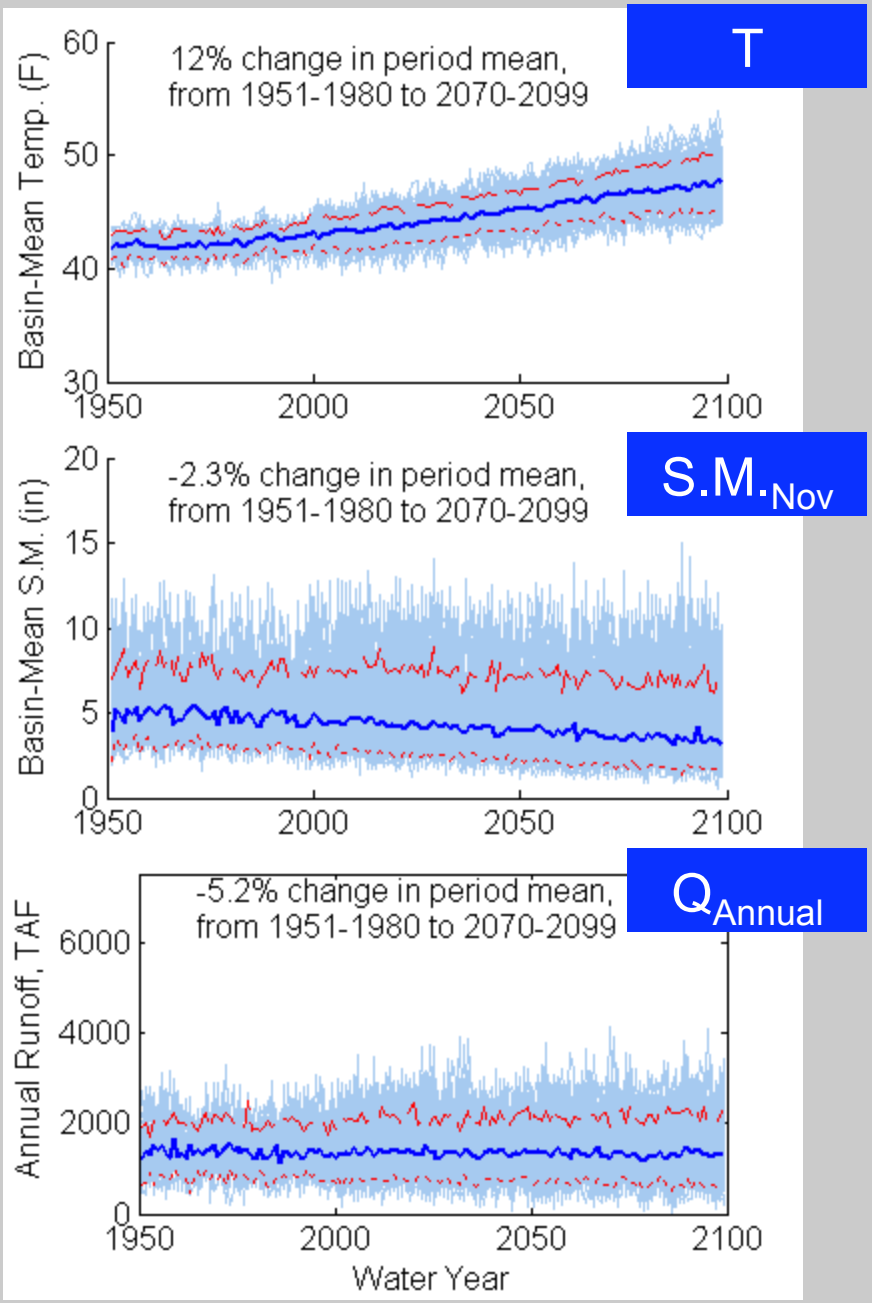
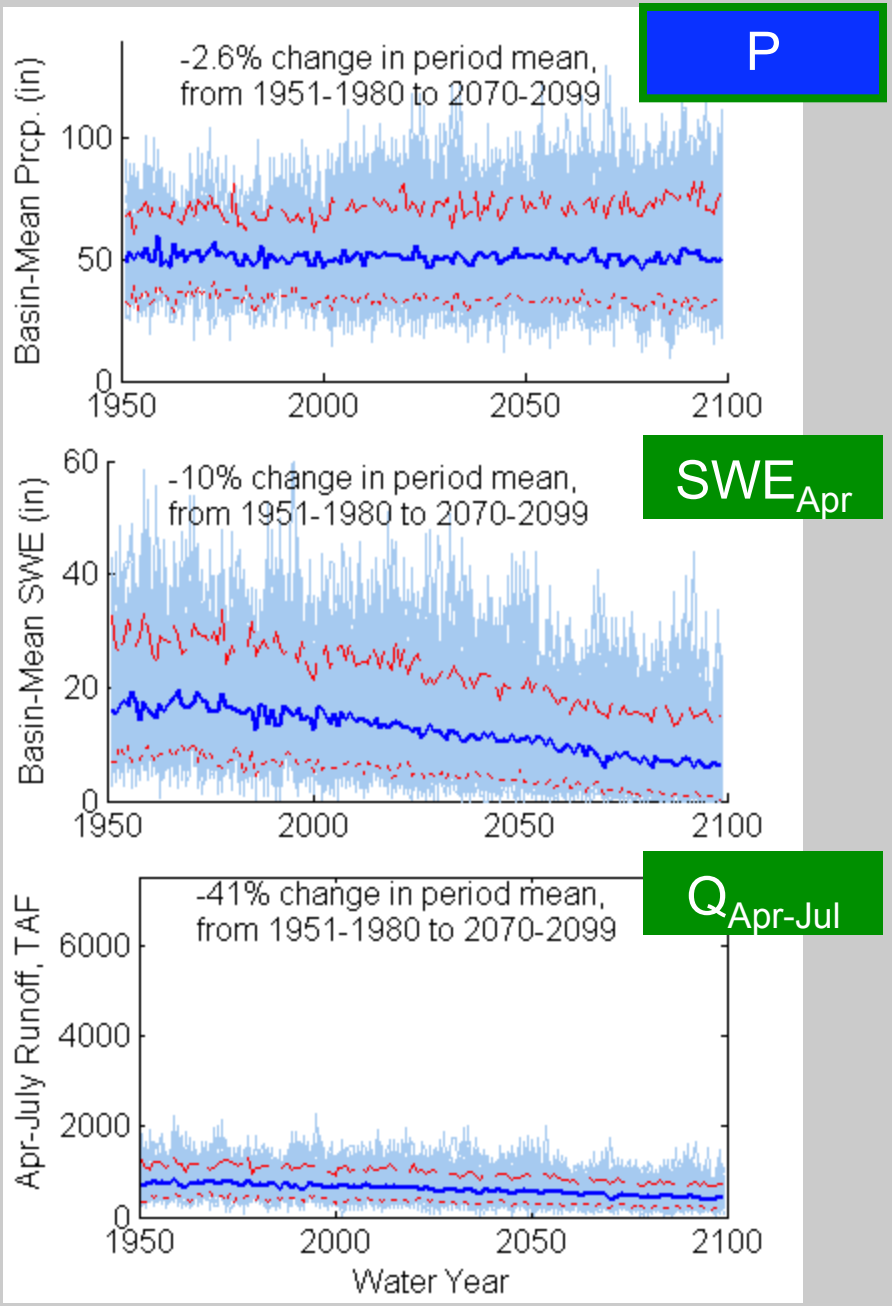
Example Hydroclimate Projections – Trinity Basin





Making Forecast Projections
(~consistent with NRCS & NWS procedures)

- Statistical Framework
  - PC Regression: Q = function of $SWE_{At\text{-}Issue}$ and $P_{antecedent}$
- Predictors and Predictands
  - Predictands: $Q_{Apr\text{-}Jul}$, $Q_{Mar\text{-}June}$ (Jan, Feb, Mar, Apr issues)
  - Predictors distributed by subbasins and their elevation zones
- Consolidating Predictors:
  - Focused on higher elevation zones' P & SWE
- Forecast Model Updating:
  - Calibrate to retrospective 30 years …
  - Apply to next 10 years, get validation results…
  - Update model every 10 years …

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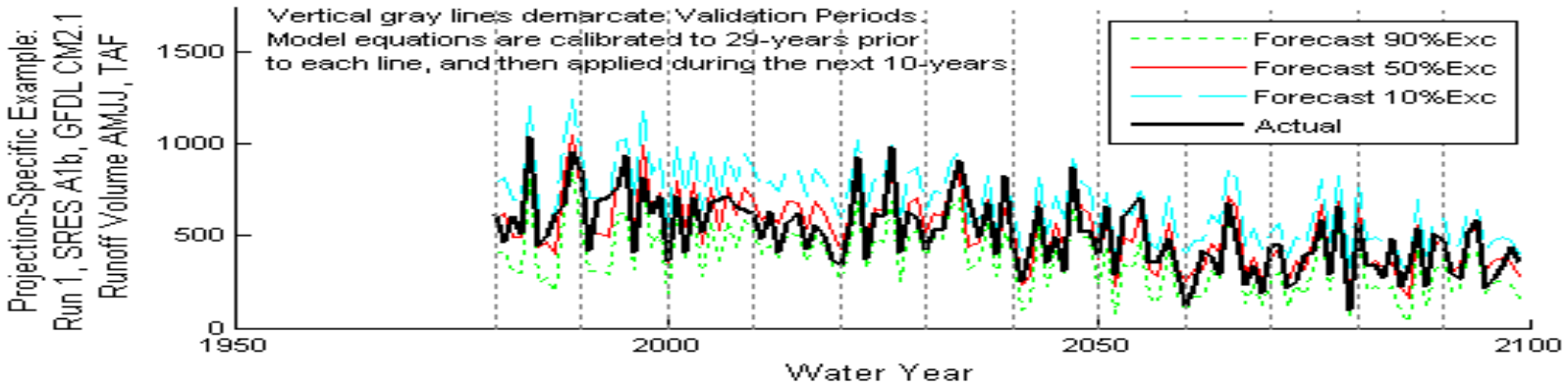
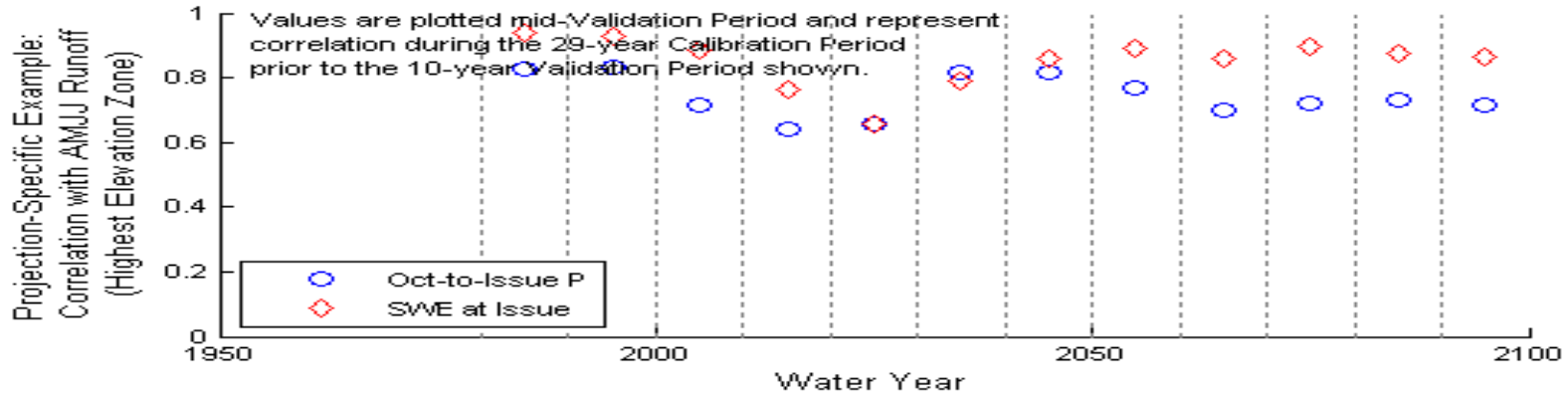
e.g., Trinity: (a) single projection of validation forecasts, (b) calib. correlations





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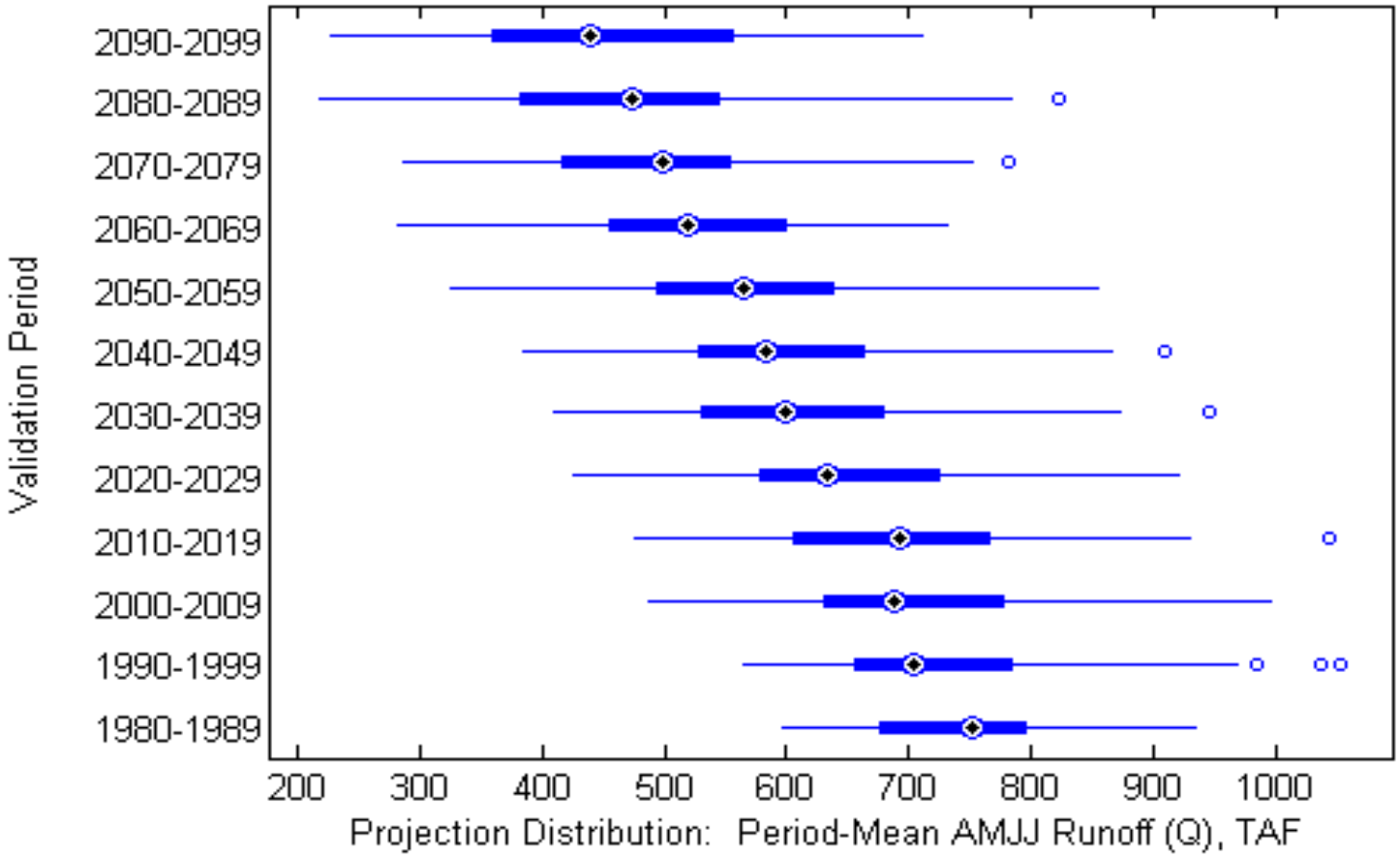
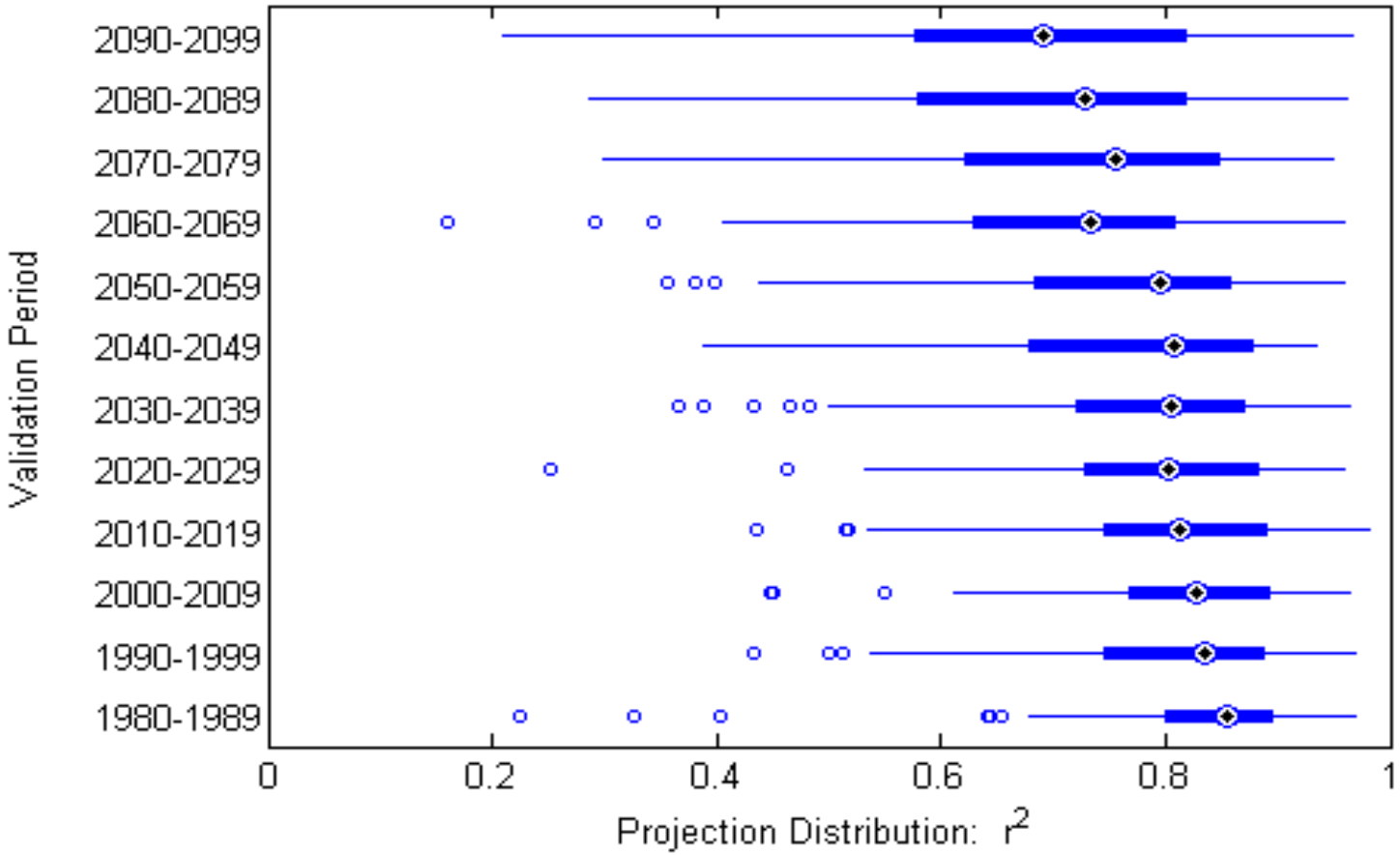
Trinity Ensemble: Hydrologic Impact ($Q_{Apr-Jul}$)



RECLAMATION

Trinity Ensemble: Predictability Impact (April Issue of $Q_{Apr\text{-}Jul}$)



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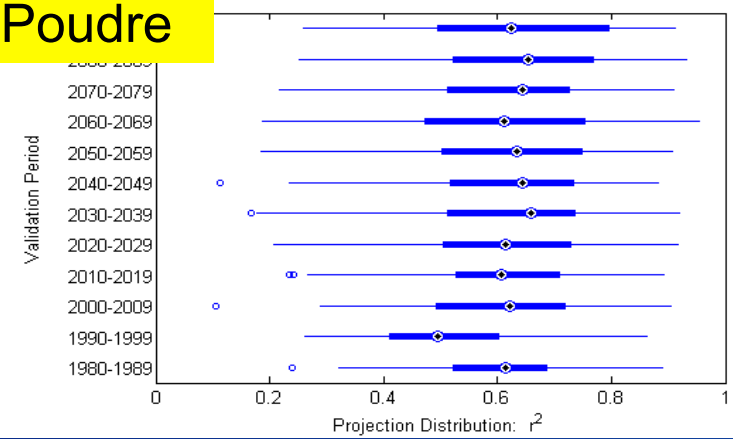
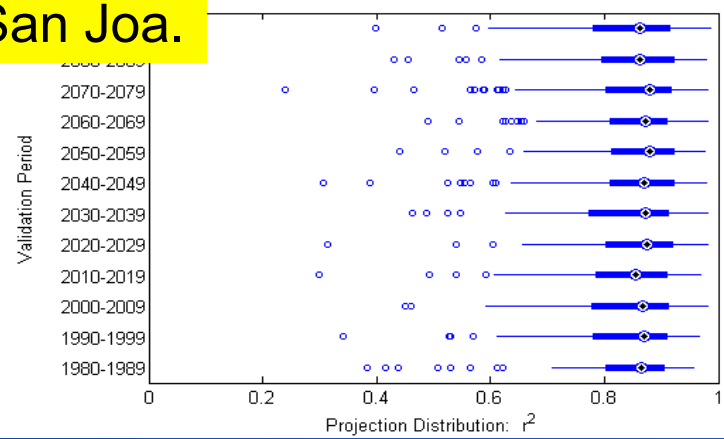
All Basins' Ensembles: $Issue_{Apr}$, $Q_{Apr\text{-}Jul}$, Predictability Impact

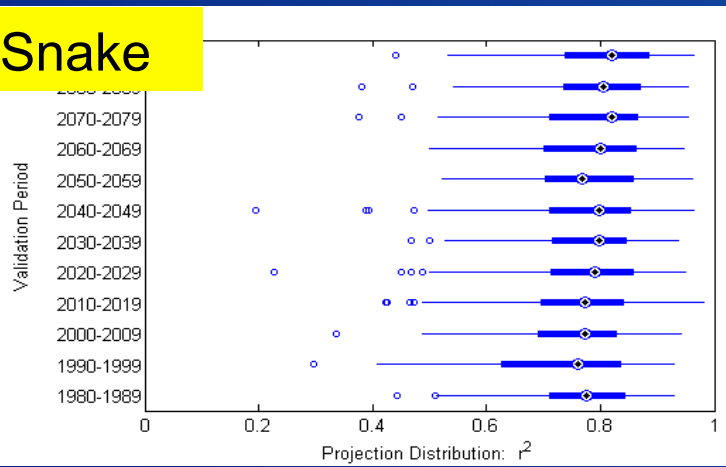
Poudre



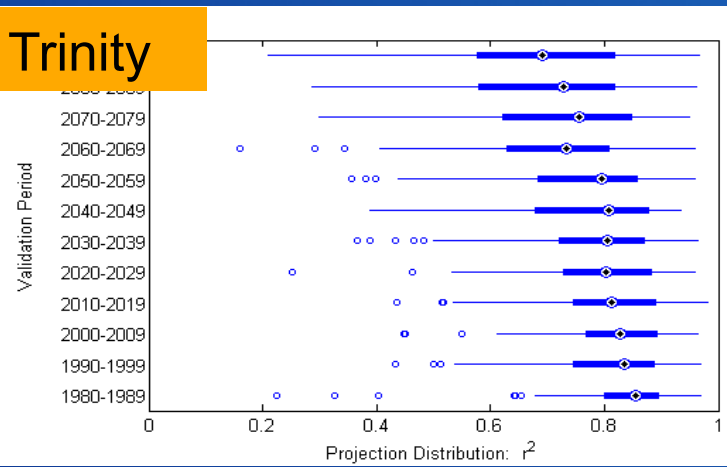
San Joa.



Snake



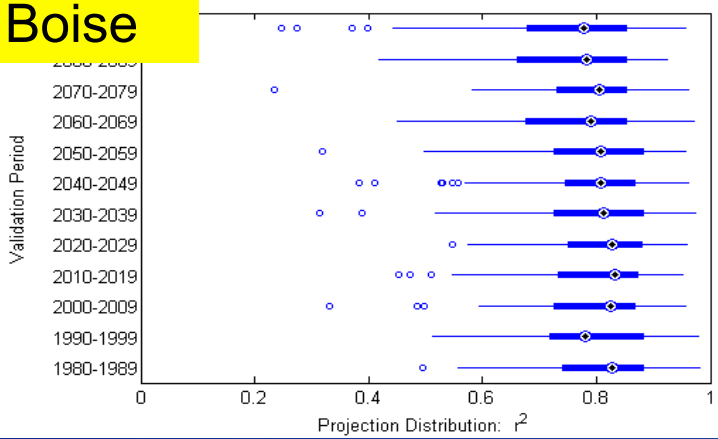
Trinity



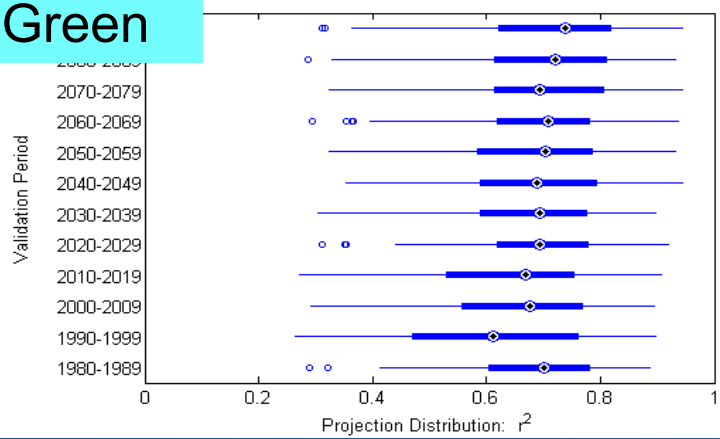
RECLAMATION

All Basins' Ensembles: $Issue_{Apr}$, $Q_{Apr\text{-}Jul}$, Predictability Impact

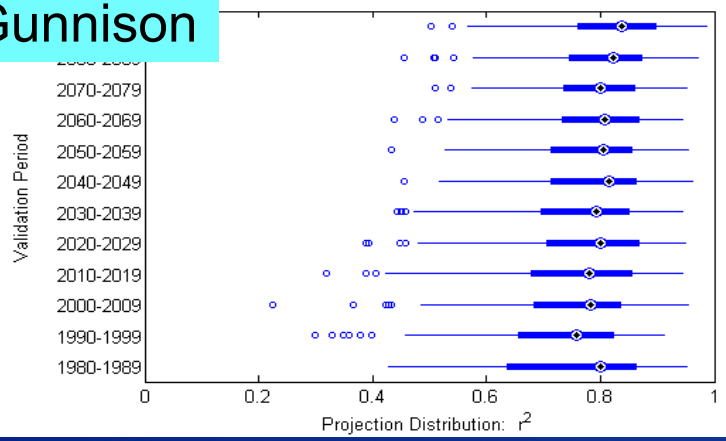
Boise



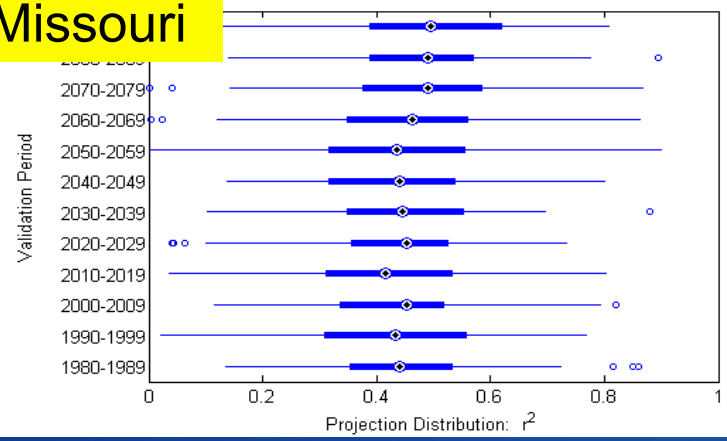
Green



Gunnison



Missouri



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Uncertainties

- Climate Projections
  - specifying emissions, GCMs, initial conditions…
- Hydrologic Simulation Model
  - model structure, parameterization, weather inputs
    - historical weather used to calibrate hydrology model differs from that used to bias-correct and spatially downscale climate projections
- Water Supply Forecast Model
  - Model Structure, Predictor Selection, etc
  - Mean-Area Predictors, unrealistic information sampling
  - Why are some results so extreme (good or bad)?

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Study #2: Period-Change in Predictability, Pacific Northwest basins

- Acknowledgment to Univ. WA Climate Impacts Group (UW CIG) for providing simulated hydroclimate data.
- Study completed as an interagency effort sponsored by Reservoir Management Joint Operating Committee

RMJOC (2010) "*Climate and Hydrology Datasets for use in the RMJOC Agencies' Longer-Term Planning Studies: Part I - Future Climate and Hydrology Datasets*", prepared jointly by Bureau of Reclamation, Bonneville Power Administration, and U.S. Army Corps of Engineers, 209pp.

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Approach

1. Define period climates
   - UW CIG HB2860 Data:
     - Historical, six scenarios of both Hybrid-Delta (HD) 2020s and HD 2040s.
     - Each climate (historical, HD####) features variabiliity from obs.1916-2006.

2. …make Basin Hydroclimate data (P, SWE, Runoff)
   - UW CIG's 1/16º VIC app. of the Columbia-Snake River Basin

3. …make Forecast data
   - Single forecast model calibrated to climate period (omniscience)
     - Unlike Study #1, no model decadal updating in-period, otherwise similar
   - *Spatial predictor samping constrained to be near real monitoring!*
4. Evaluate calibration forecast skill across climates.
   - Various metrics (r^2, RMSE)

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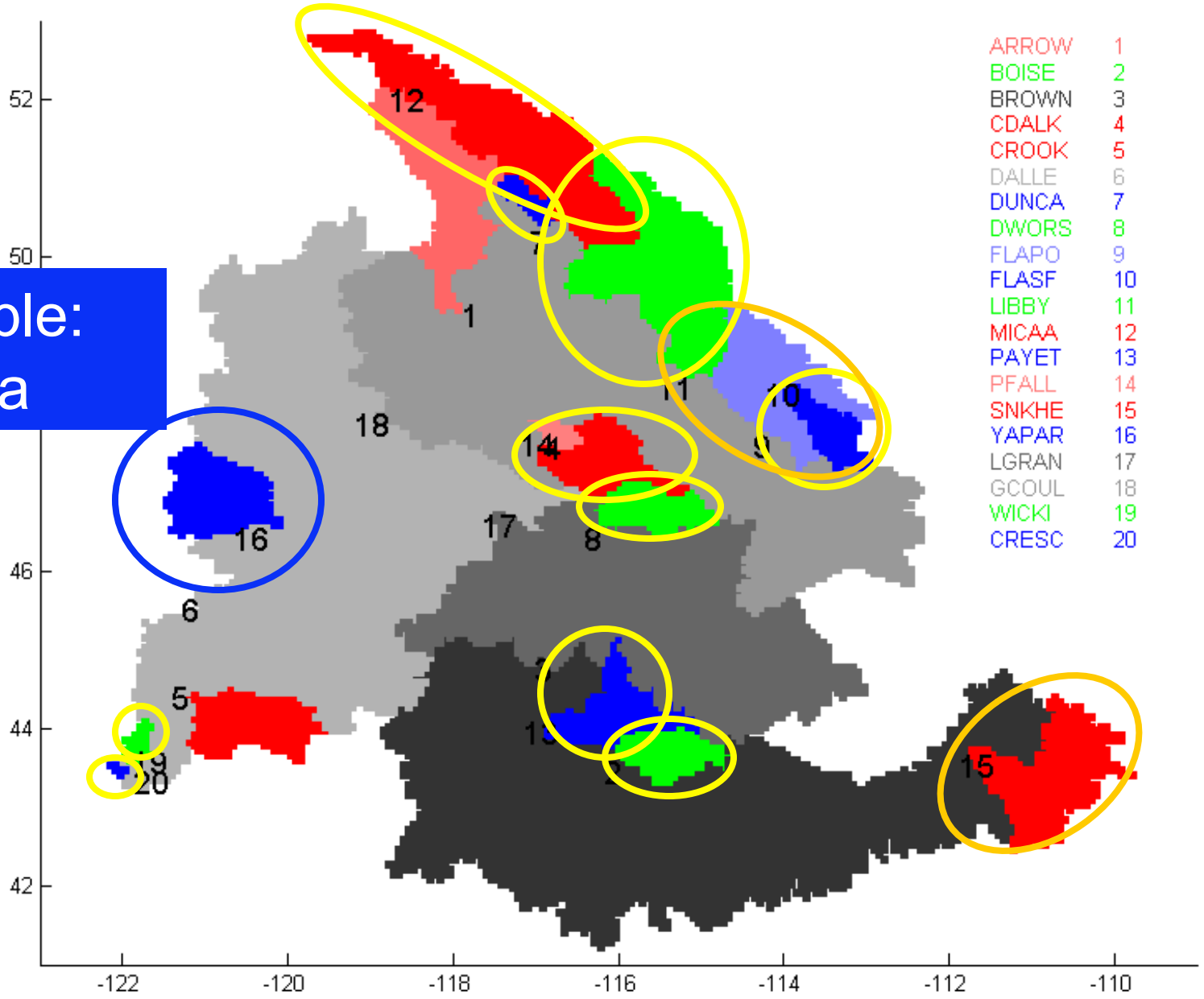
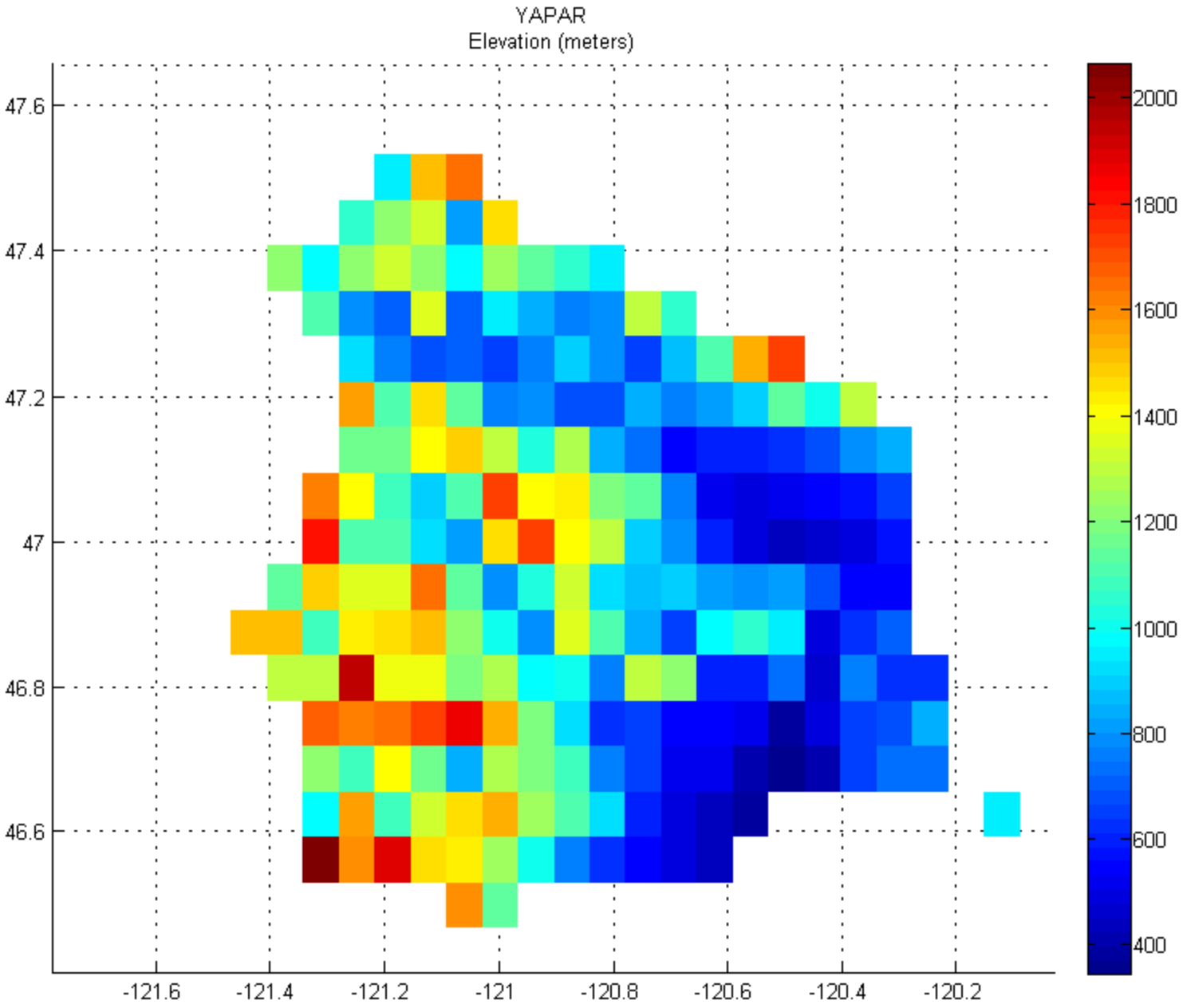
Example: Yakima




YAPAR
Elevation (meters)
47.6
47.4
47.2
47
46.8
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-121.4
-121.2
-121
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-120.6
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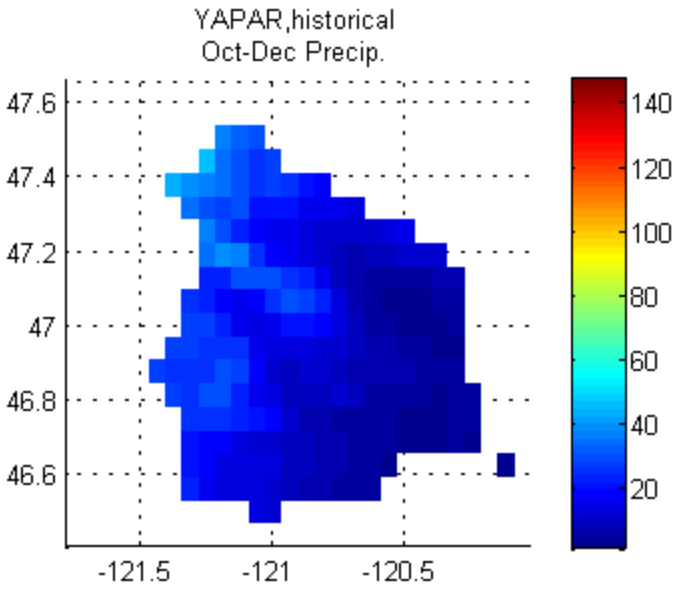
YAPAR,historical
Oct-Dec Precip.
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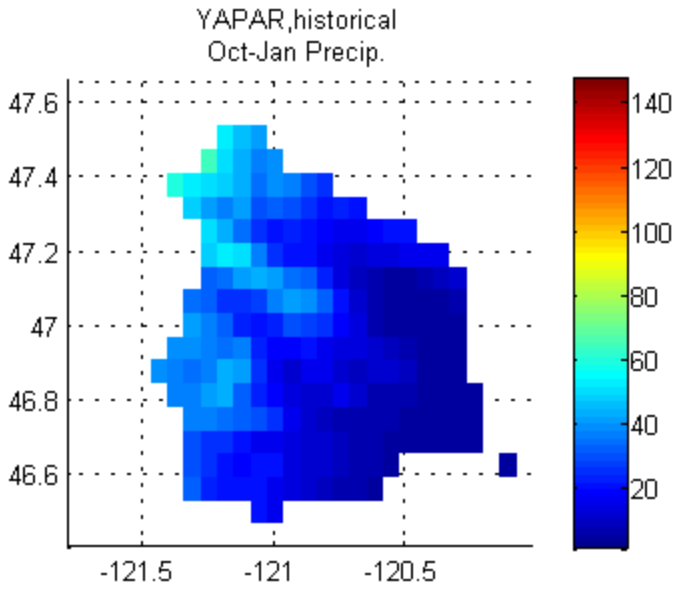
YAPAR,historical
Oct-Jan Precip.
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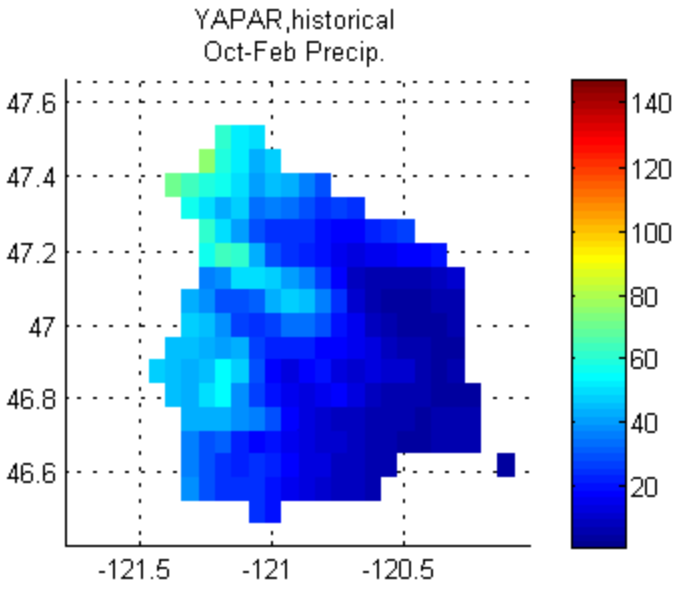
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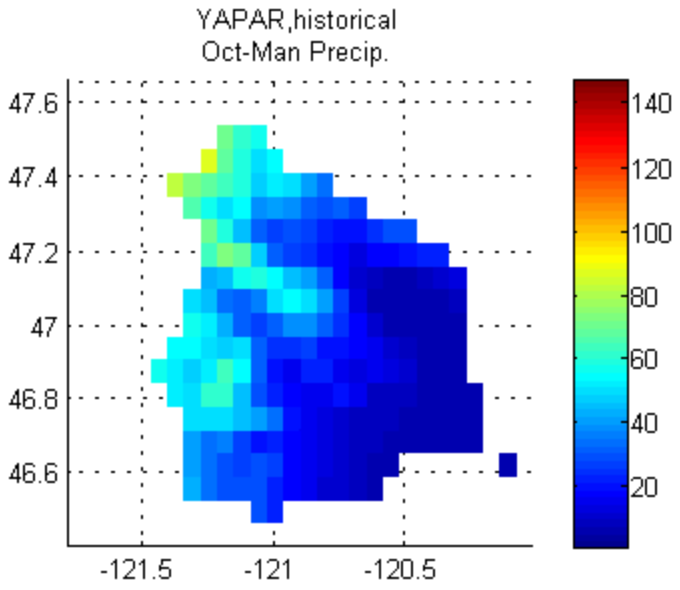
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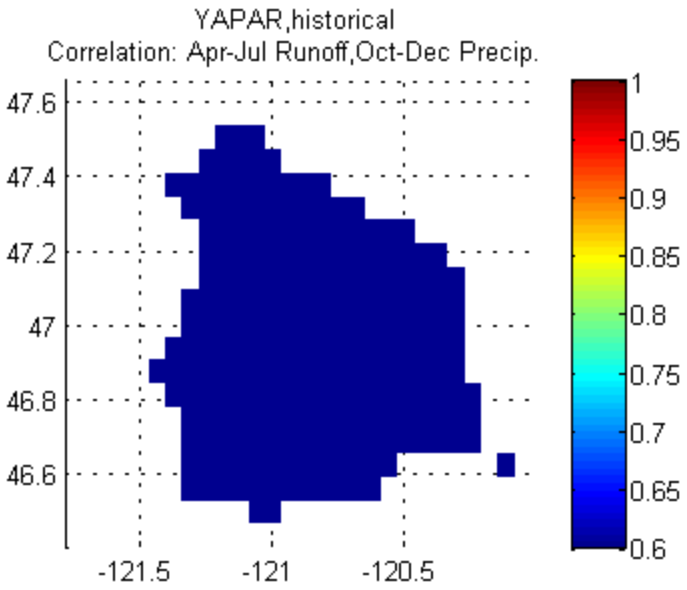
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Correlation: Apr-Jul Runoff,Oct-Dec Precip.
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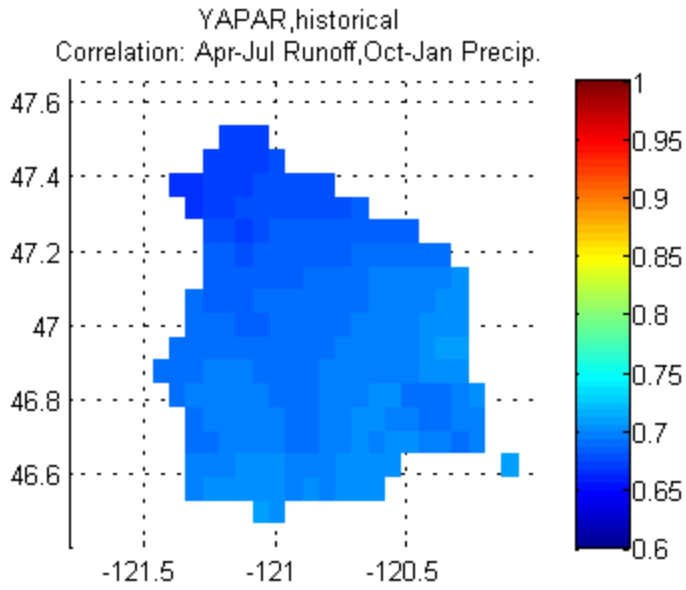
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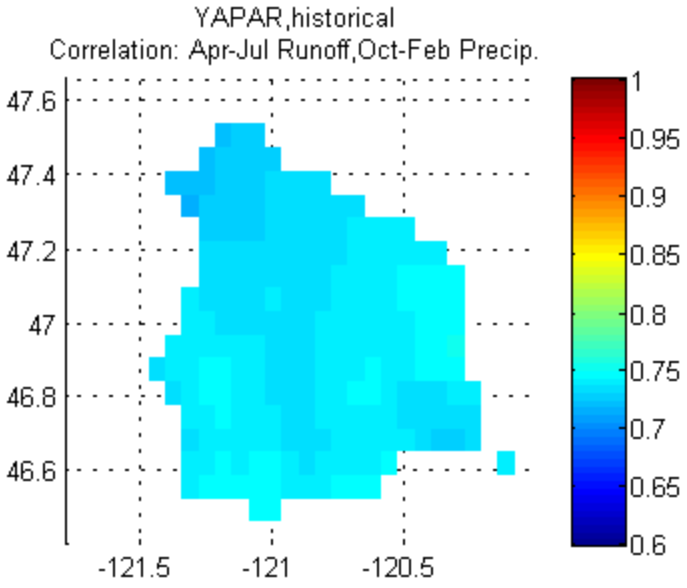
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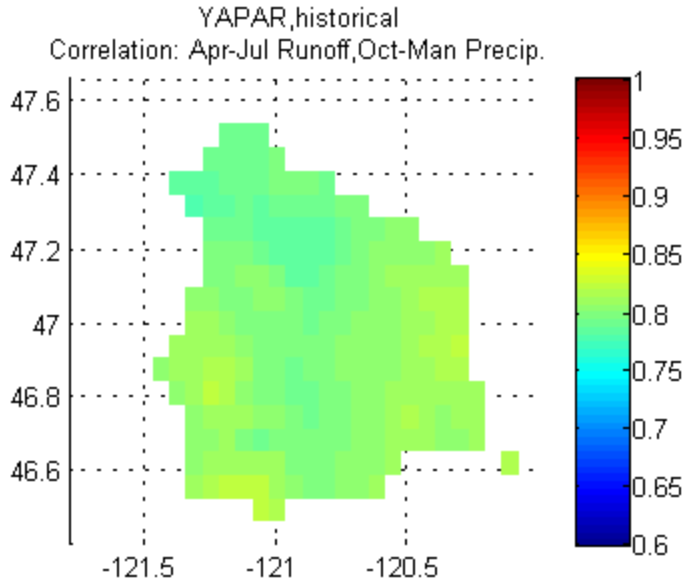
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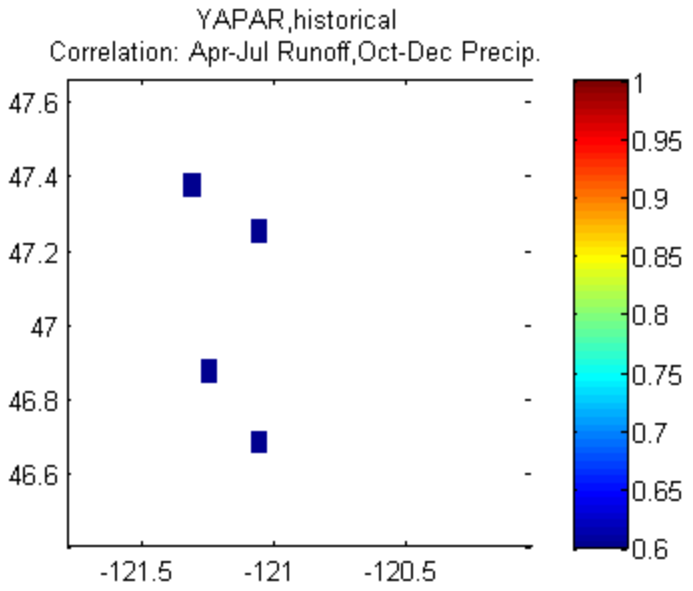
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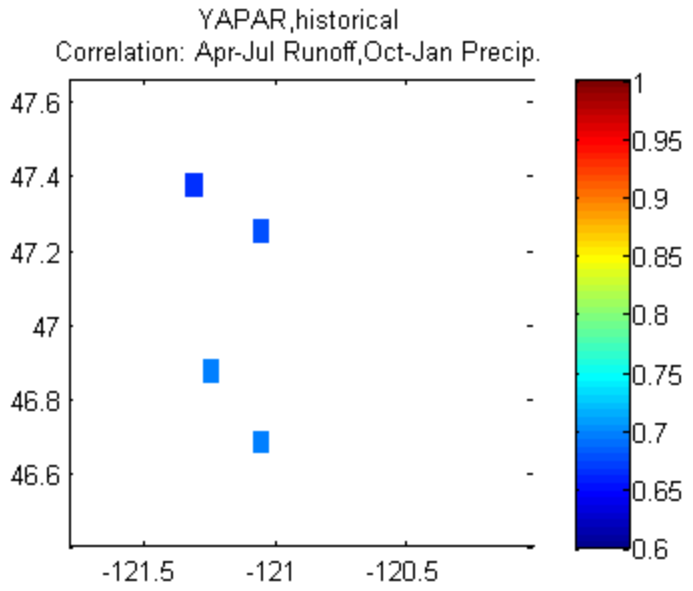
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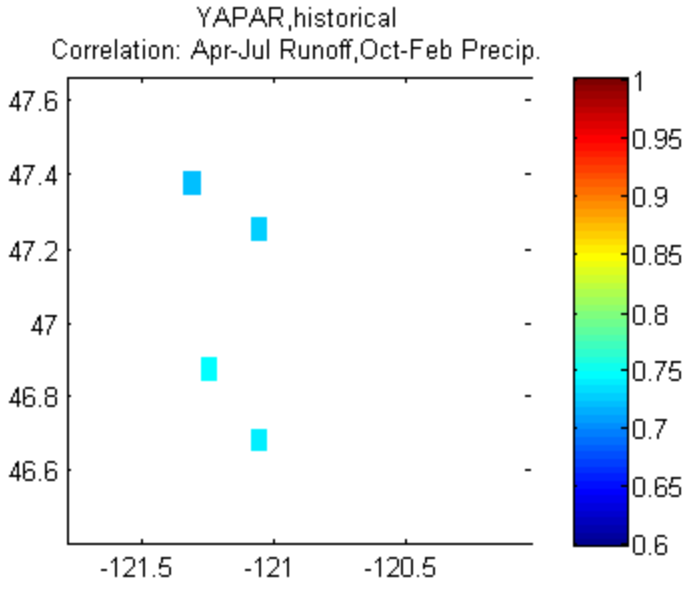
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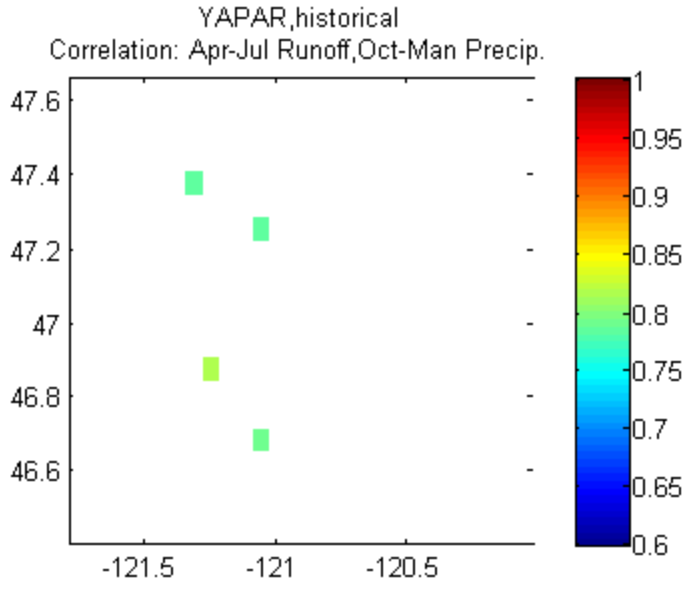
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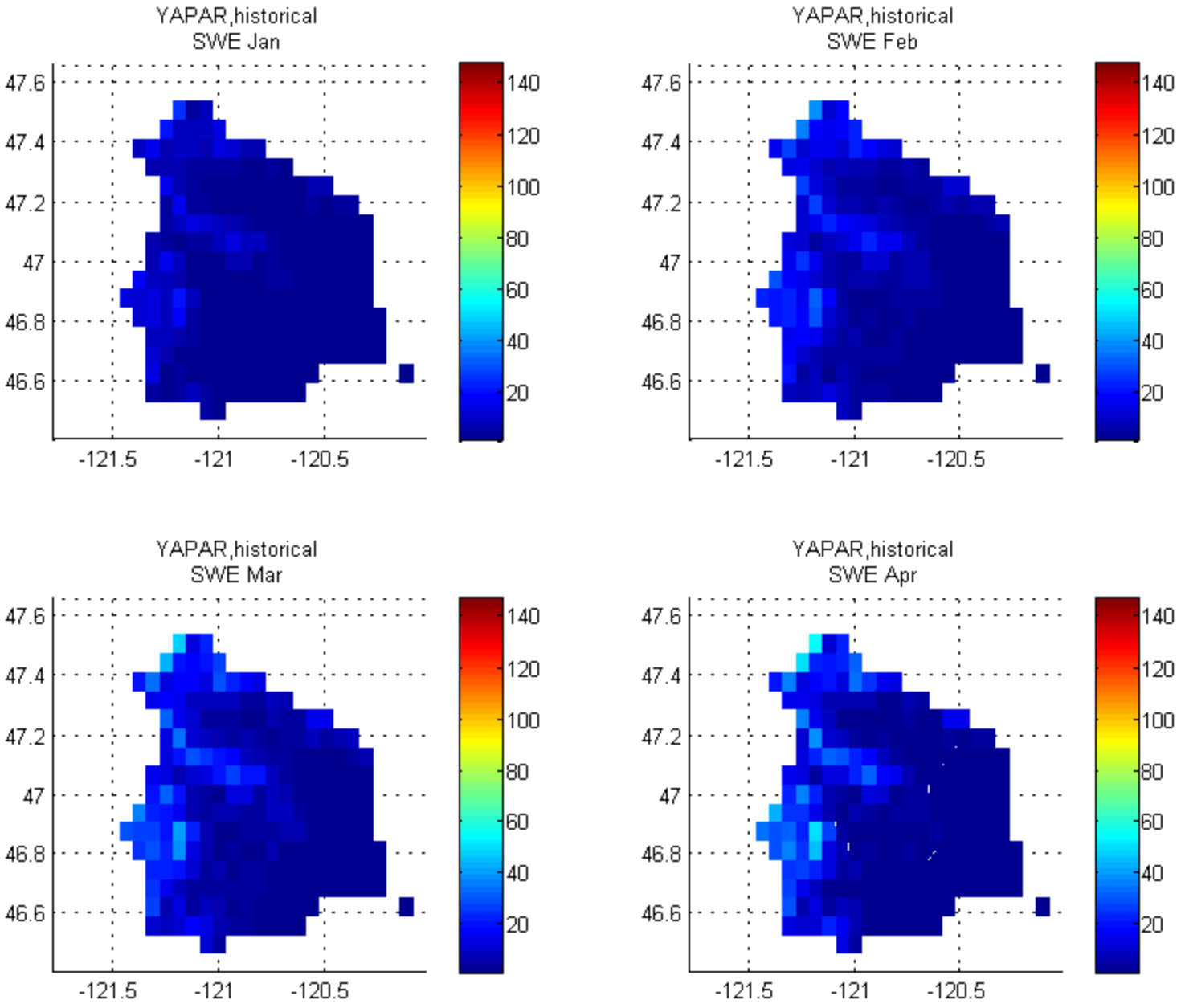
YAPAR,historical
SWE Jan
YAPAR,historical
SWE Feb
YAPAR,historical
SWE Mar
YAPAR,historical
SWE Apr
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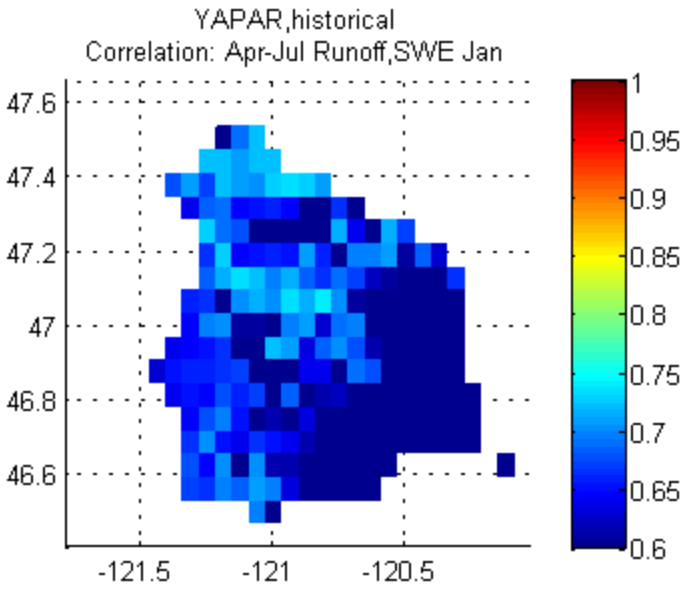
YAPAR,historical
Correlation: Apr-Jul Runoff,SWE Jan
47.6
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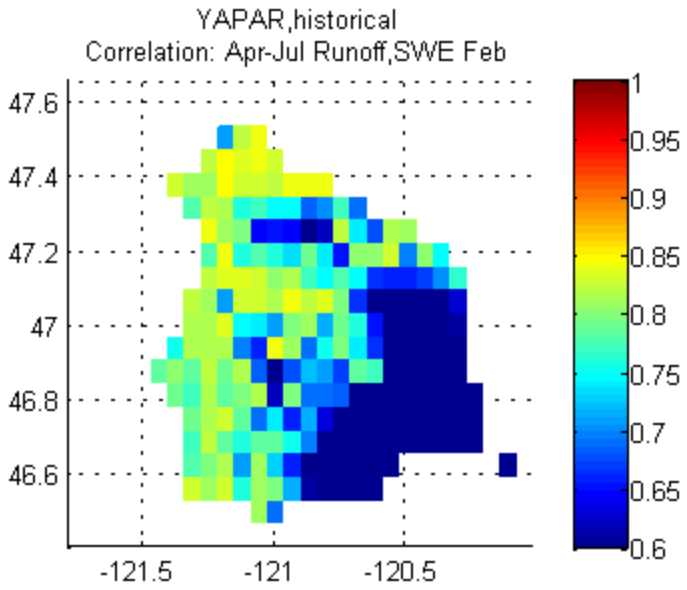
YAPAR,historical
Correlation: Apr-Jul Runoff,SWE Feb
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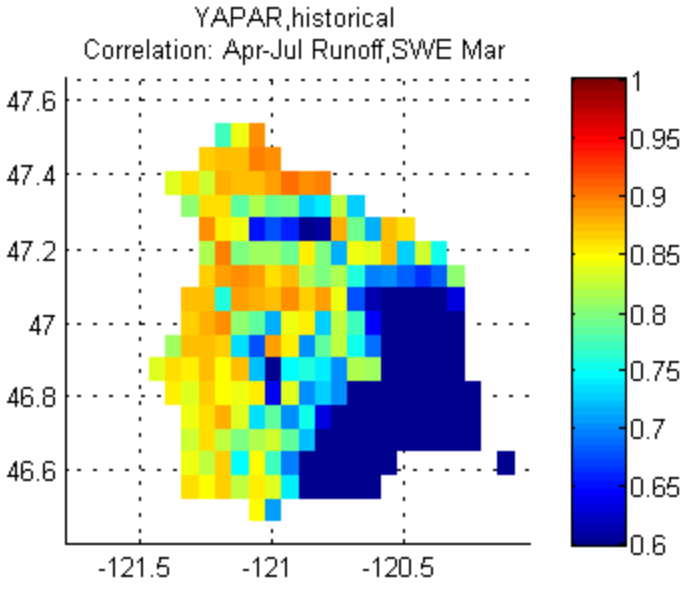
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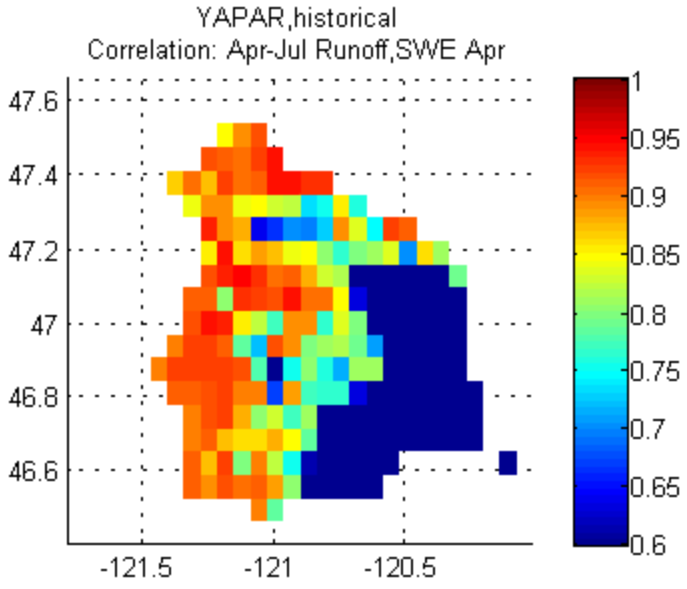
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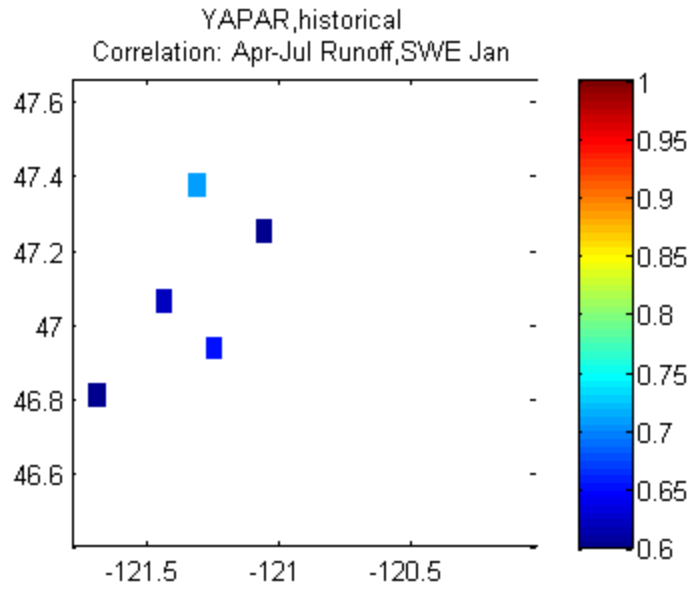
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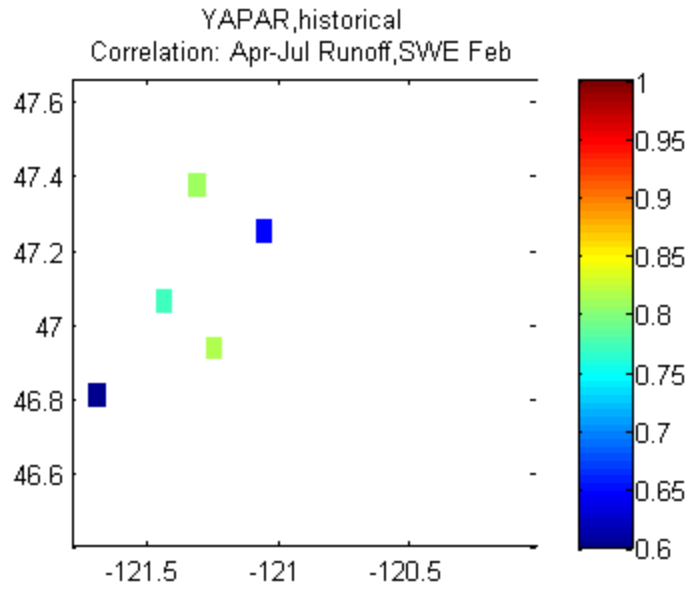
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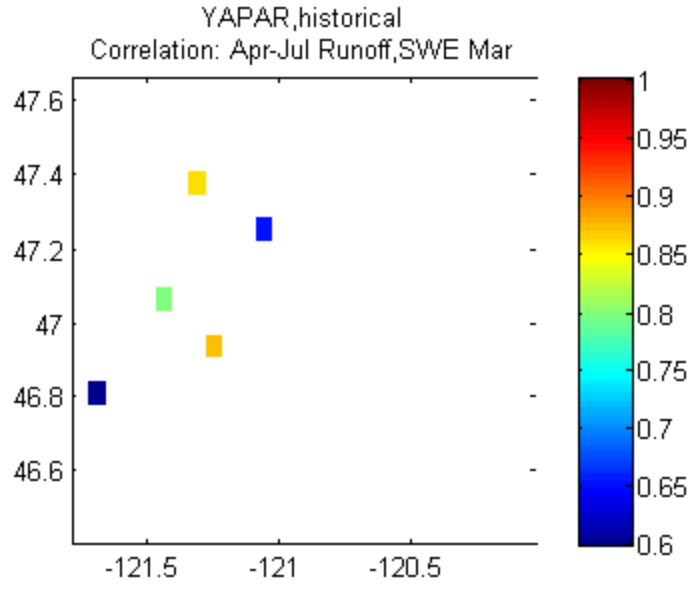
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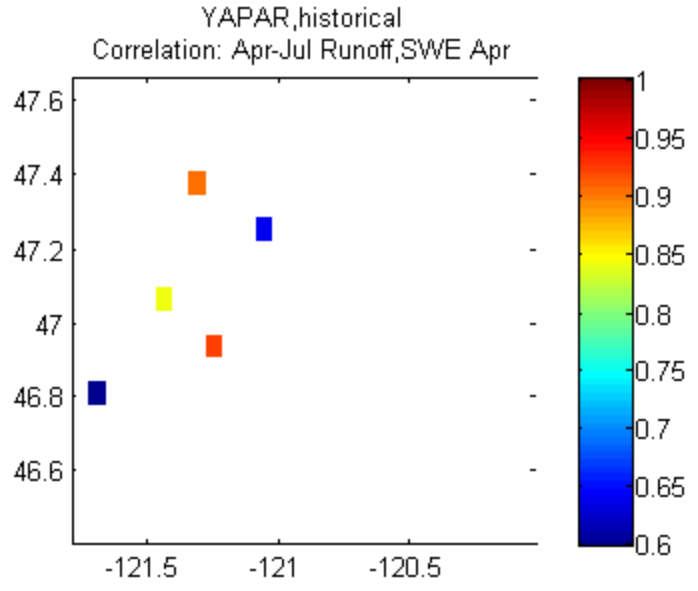
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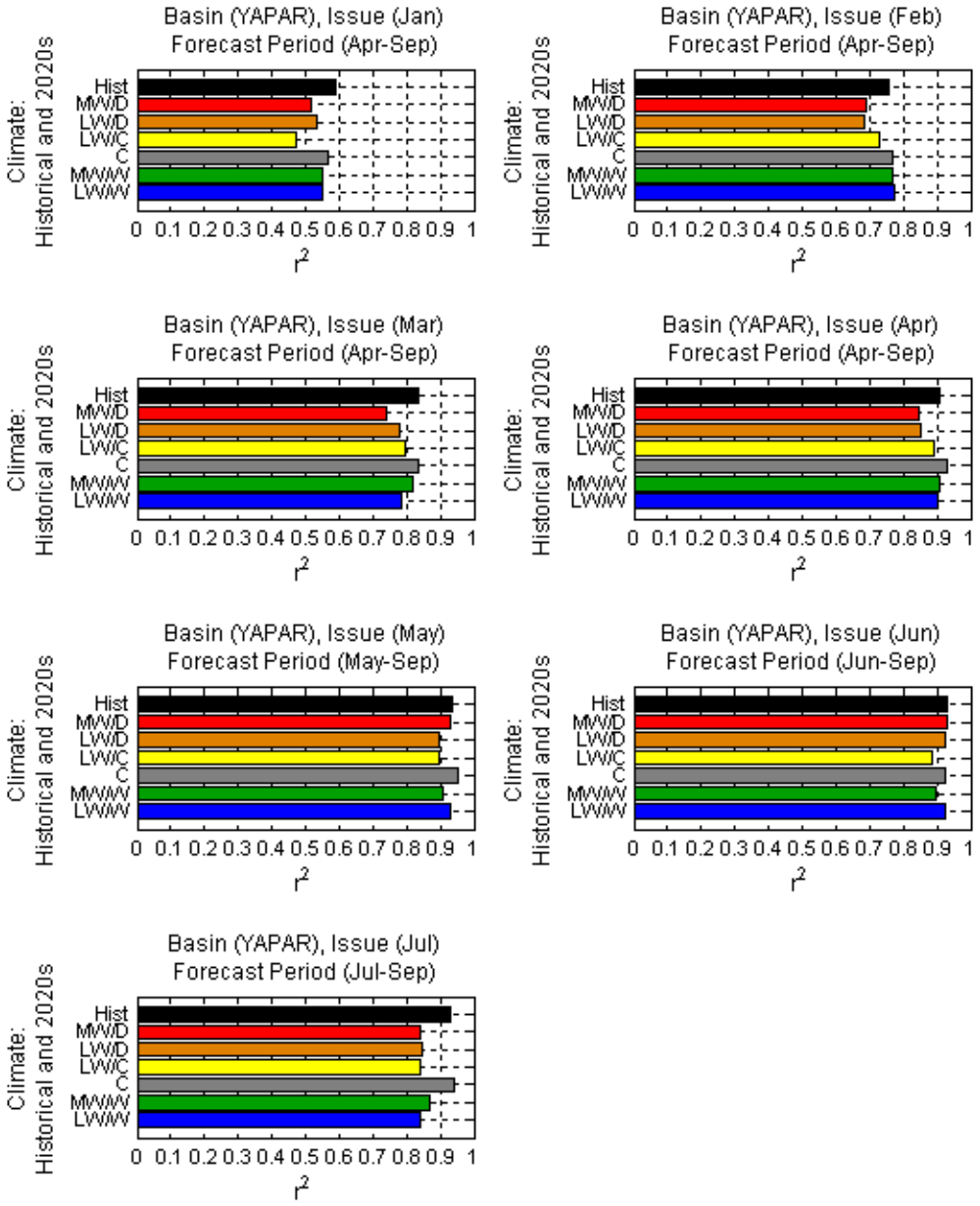
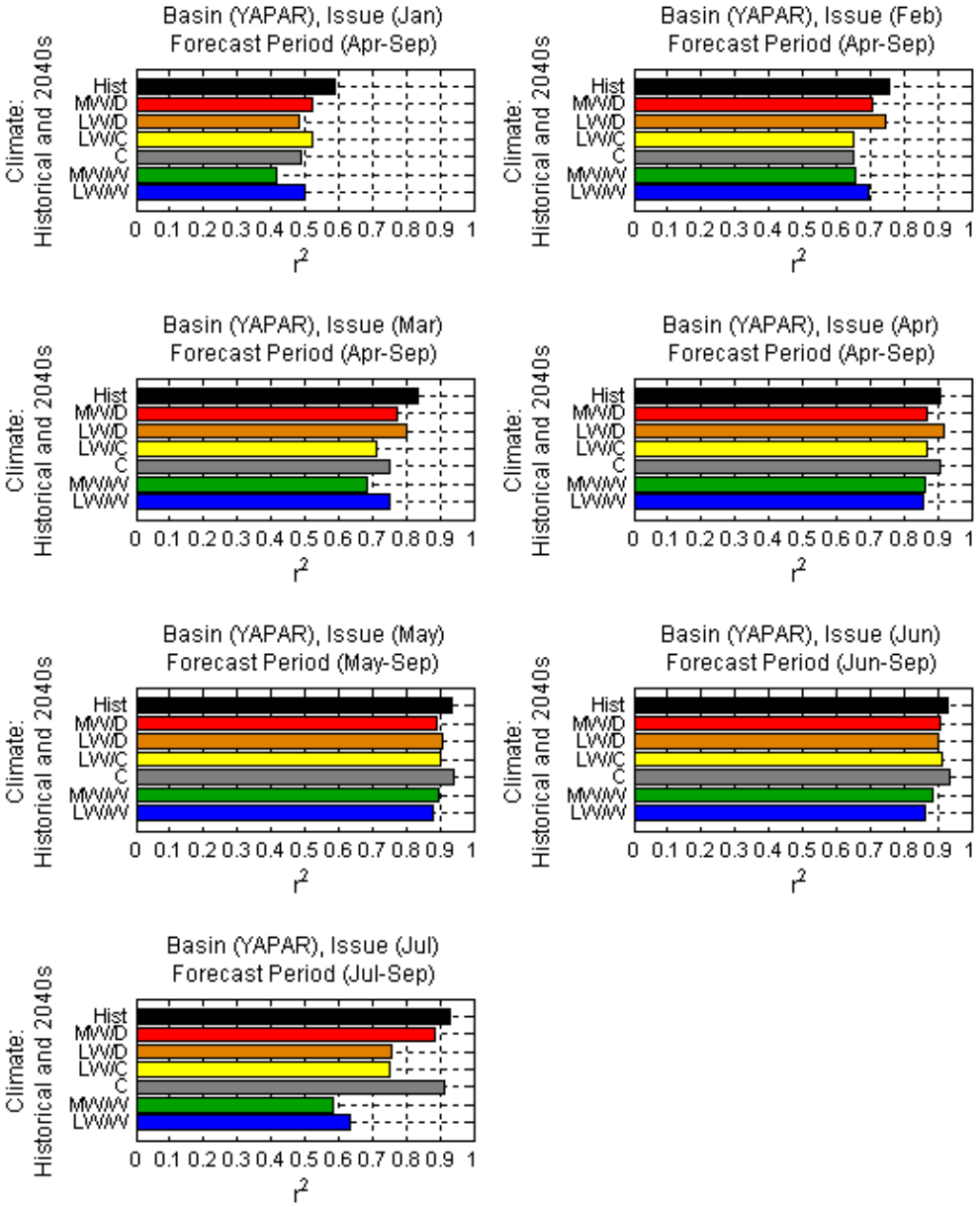
Regression Results: r^2, Historical (black) and HD 2020s



Regression Results: r^2, Historical (black) and HD 2040s



Reactions

- For most other PNW basins, predictability in HD2020s and HD 2040s climates found to be similar to that in Historical, perhaps slightly weaker.

- Impacts on predictability seems most apparent for early Winter forecast issues and late Spring forecast issues
  - (e.g., January issues of spring-summer volume, or June issue for summer volume)…
  - This seems physically intuitive (i.e., warming leads to less early season snowpack which negatively affects early Winter forecasting, or warming leads to less late-season snowpack and negative affects late Spring forecasting).

Summary

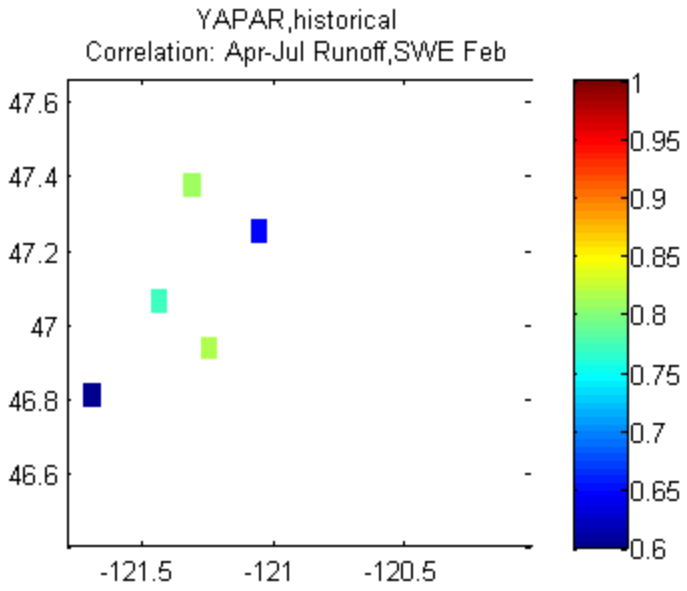
- We've introduced a framework for:
  - generating forecast projections consistent with hydroclimate projections (Study #1)
  - generating period-shifts in forecast characteristics consistent with hydroclimate changes (Study #2)
    - We're apply Study #2 framework within the RMJOC reservoir operations impact assessment.

RECLAMATION

Summary

- Predictability impacts:
  - (Study #1) onset of reduce predictability appears to vary among Western U.S. basins; sooner for basins with more “at-risk” snow...
  - (Study #2) early- to mid-21st century, it appears that early Winter and late Spring forecast issues will be impacted first… However, results were limited to sampling predictor information from real-world monitoring. Are these locations ideal for forecasting service in the future?

RECLAMATION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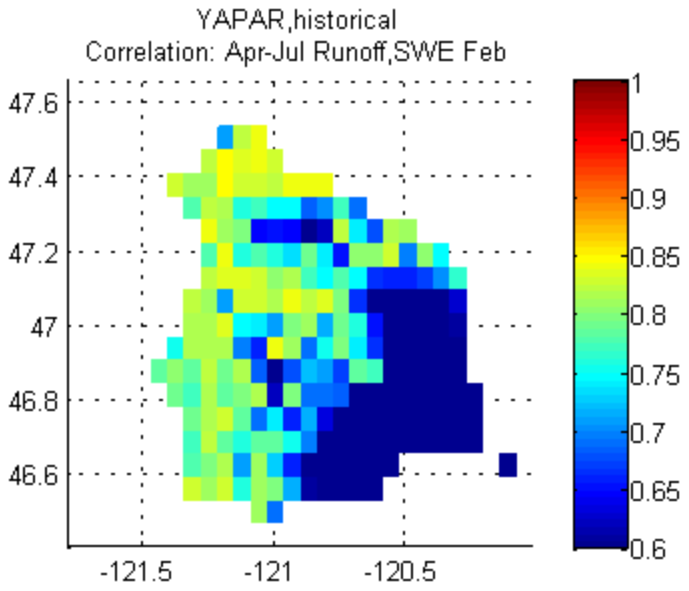
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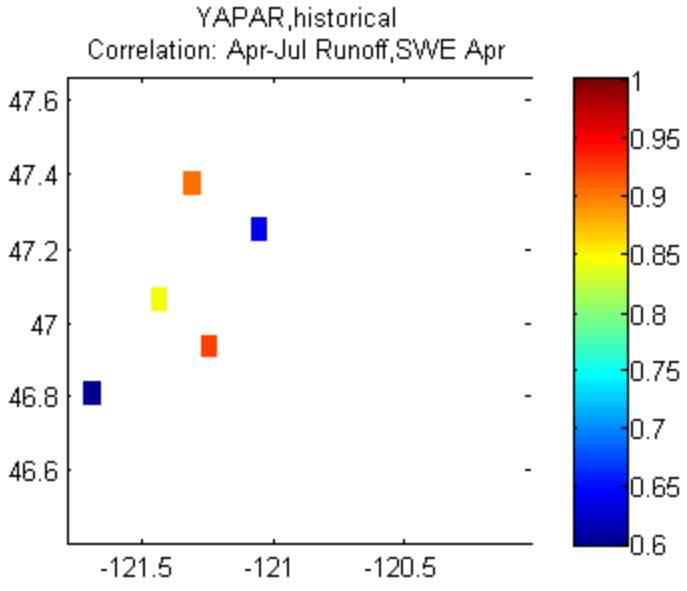
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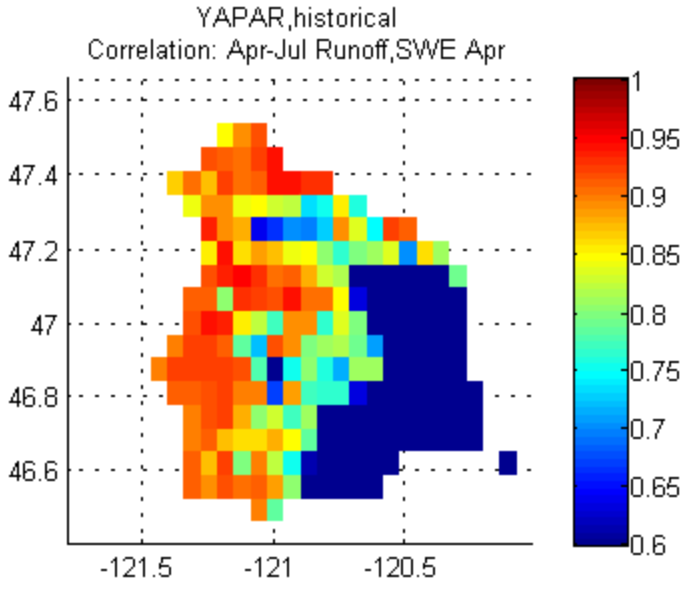
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